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**Intermountain
Research Station**

Research Paper
INT-380

Effects of Persistent Volcanic Ash on Douglas-fir in Northern Idaho

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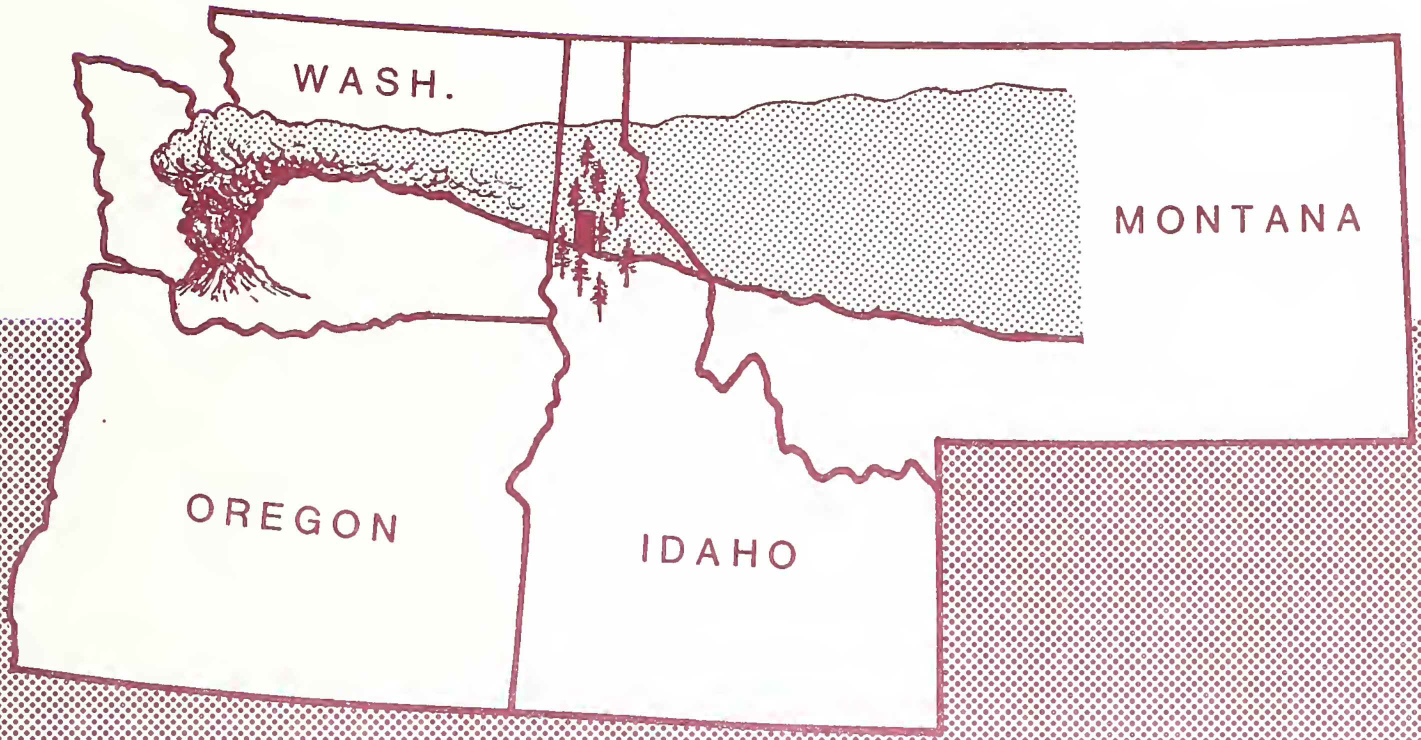

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RESEARCH SUMMARY

The eruption of Mount St. Helens on May 18, 1980, deposited tephra (volcanic ash) on forests of northern Idaho. Tephra persisted on foliage of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco), with 12.8 to 15.7 mg ash/gram tissue dry weight remaining on 1979 and 1980 needles 16 months after the eruption. Although total chlorophyll was reduced and chlorosis occurred in needles from affected stands, the persisting tephra did not significantly influence tree growth—the number of needles per stem segment, their dry weight, and radial stem increment were unaffected. We conclude that ashfall had a slight but only temporary effect on Douglas-fir in northern Idaho.

August 1987

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INTRODUCTION

The eruption of Mount St. Helens on May 18, 1980, deposited about 1.5 to 2.0 km^3 of tephra (volcanic ash) on farm, range, and forest lands of eastern Washington, northern Idaho, and western Montana (Hammond 1980). The explosion destroyed coniferous forests near the volcano. To the east, acaulescent and prostrate vegetation was damaged by ash loading (Mack 1981), and agricultural crop losses were estimated at $100 million (Cook and others 1981). Ash accumulation on apple leaves reduced photosynthetic rates by nearly 25 percent and increased photorespiration (Kennedy 1981). Near the volcano, needles of Pacific silver fir (*Abies amabilis* Dougl. ex Forbes) were damaged by persistent ash (Seymour and others 1983). Chlorosis occurred within 3 weeks of the eruption and was attributed to high foliar temperatures induced by tephra on the needles. Seymour and others (1983) concluded the ash probably altered the surface characteristics of the needles, allowing larger solar heat flux. Hinckley and others (1984) found that ash deposition near the blast zone reduced height and diameter growth of both Pacific silver fir and western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) and reduced 1980 ring width of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco). Removal of tephra from needles of Pacific silver fir and noble fir (*Abies procera* Rehd.) increased subsequent height growth (Zobel and Antos 1985).

In the fall of 1980, needles of Douglas-fir growing in northern Idaho, 480 km from the volcano, retained 420 mg of tephra per gram needle dry weight, but needles of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) were free of ash (Bilderback and Slone 1986). This study was conducted to determine if persistent ash deposits affected chlorophyll content and growth of the Douglas-fir. Ponderosa pine was not studied because tephra was not persistent on its foliage.

METHODS

Two stands of trees, one tephra-coated and the other unaffected, were selected for comparison. The stand with tephra-coated foliage was 27.2 km south of Coeur d'Alene, ID, about 480 km northeast of the volcano. This site received about 1 cm of tephra. The control stand was located 11.2 km northeast of Coeur d'Alene, nearly out of the plume path. It received less than 0.01 cm of tephra. Both locations were at 658 km elevation, faced south, and had slopes varying from 0 to 40 percent. Habitat type, an indicator of site similarity (Pfister and others 1977), was *Pseudotsuga menziesii/Physocarpus malvaceous* at both locations.

The stands were similar in structure. The average diameters, measured 1.37 m above ground, were 41.4 cm and 45.5 cm for the tephra and control stands, respectively. The control stand was about 100 years old and the tephra stand about 85. The tephra stand was more dense, with 343 stems per hectare compared to 188 for the control.

In September 1981, 16 months following the eruption, six plots were installed 45 m apart along a randomly located transect in the control stand. Five plots were installed along each of two parallel, randomly located transects at the tephra stand. Within each control plot, two midcrown branches from opposing sides of five dominant/codominant Douglas-fir trees were clipped, placed in plastic bags, and transferred to a freezer for storage. At the tephra stand, six trees, similar in size to those selected in the control, were sampled at each plot. Thus, a total of 90 trees were sampled in the study. To determine the influence of ash on bole radial growth, two increment cores were taken 1.37 m above ground level, 90 degrees from each other around the bole of each sample tree.

To determine the amount of persistent tephra on the 1979 and 1980 foliage, 20 needles of each age class were randomly selected from each of the two collected branches of each tree and washed in a small volume of water. The suspension was filtered and tephra collected on preweighed Millipore filters. The filters and needles were ovendried and weighed to determine the amount of tephra (mg/gram needle dry weight) that was on the needles prior to washing.

For each tree sampled, all lateral branchlets bearing 1979, 1980, and 1981 needles were clipped from each sample branch. Branchlets were cut at the nodes, and internodes were segregated by date of origin—1979, 1980, and 1981. Thus, 270 segments were evaluated: 90 trees × 3 years/tree. All needles of three randomly selected internodes within each age class were counted and assessed for chlorosis on a scale of 0 (no damage) to 4 (brown needles). Then they were stripped from the shoots and pooled.

To determine if persistent ash affected chlorophyll content, five needles were randomly selected from each age class, split lengthwise with a razor blade, pooled, and extracted with 95 percent methanol for 72 hours. A total of 270 extractions and analyses were done (90 trees × 3 ages/tree). Chlorophyll was determined by the method of Mackinney (1941).

Total chlorophyll was computed as:

$$Chl = 22.5 \times A_{650} + 4.0 \times A_{665}$$

where A is the absorbance at 650 and 665 nm.

To determine whether the tephra influenced radial stem growth, two growth ratios were computed for all sample trees:

$$1.\ \frac{G_{1980}}{\bar{X}G_{(1970\text{-}1979)}} \quad \text{and} \quad 2.\ \frac{G_{1980}}{G_{1979}}$$

where G is the radial growth for a year or period, measured on the increment core.

Variables were compared between stands using standard *t*-test procedures (Sokal and Rohlf 1969).

RESULTS AND DISCUSSION

Five months after eruption of Mount St. Helens, needles of Douglas-fir in northern Idaho receiving about 1 cm of tephra were still heavily coated on both surfaces with 420 mg of tephra per gram needle dry weight (Bilderback and Slone 1986). The tephra had not been dislodged from the needles even though the region received 17.5 cm to 24.3 cm of summer precipitation. The 1979 and 1980 fir needles at that site retained 15.7 and 12.8 mg of tephra per gram needle dry weight, respectively, 16 months after the eruption (table 1). In contrast, foliage from trees growing at the control site had only 15 mg of tephra per gram of needle dry weight 5 months after eruption (Bilderback and Slone 1986) and no ash thereafter (table 1). Samples from one tree in the tephra stand were lost, reducing the trees sampled from 90 to 89.

Total chlorophyll was significantly less ($P \leqslant 0.05$) in the 1979 and 1980 Douglas-fir needles from the tephra-laden stand (table 1). These needles also were chlorotic. A small but significant amount of chlorosis also occurred in 1981 needles from the ashed stand, even though these needles were never exposed directly to the tephra. Although the reason for chlorosis of new needles is not understood, it appeared to be related to ashfall.

Seymour and others (1983) investigated foliage damage to Pacific silver fir following ashfall. Persistent ash around the needles did not mechanically or chemically damage the cuticle of needles they studied or alter water potentials but significantly elevated needle temperature by 10 °C. Tephra deposition apparently altered foliage geometry, and the resulting change in the energy balance of the system caused needle temperatures to increase to lethal levels (Seymour and others 1983). In a similar manner, higher temperatures caused by a coating of tephra may have caused chlorosis and a decrease in total chlorophyll of Douglas-fir needles we sampled in northern Idaho.

In our study, volcanic ash deposition did not affect the number of needles on stem segments. Primordia of needles elongating in 1981 would have been initiated in buds during 1980 when the foliage was heavily laden with ash, but

Table 1—Comparisons of chlorophyll concentration and tree growth between the control and ashed stands

Variable	Year of needle elongation	Stand Control	 Ashed	Student's *t* value	Number of observations	Probability
Ash weight on needles (mg/g needle dry weight, 16 months after eruption)	1979	0	15.7	10.41	89	0
	1980	0	12.8	11.83	89	0
	1981	—	—	—	—	—
Total chlorophyll (mg/g needle dry weight)	1979	5.39	4.86	2.20	89	0.031
	1980	5.03	4.17	3.99	89	0
	1981	3.39	3.29	0.69	89	0.489
Chlorosis code	1979	0	1.71	15.08	89	0
	1980	0	1.94	16.44	89	0
	1981	0	0.47	4.75	89	0
Needles/stem segment	1979	71	67	1.06	89	0.290
	1980	54	57	0.98	89	0.329
	1981	71	70	0.51	89	0.609
Mean needle dry weight (g)	1979	0.0037	0.0042	2.17	89	0.033
	1980	0.0028	0.0034	3.30	89	0.001
	1981	0.0030	0.0035	1.77	89	0.080
Growth ratio A[1]	—	1.14	1.07	1.02	89	0.310
Growth ratio A[2]	—	1.03	1.01	0.21	89	0.837

[1] Ratio of 1980 radial increment to mean 1970-79 radial increment.
[2] Ratio of 1980 radial increment to 1979 radial increment.

no significant difference ($P \leqslant 0.05$) was found between the two stands for 1981, 1980, or 1979 needle counts.

Average dry weight of 1979 and 1980 needles (washed) from the stand that received ash was significantly greater than from the control stand. The 1979 needles grew prior to the ashfall. Because the difference in needle dry weight between age classes was about the same before and after ashfall, the difference cannot be attributed to the ash. Stand or site factors likely were responsible.

Hinckley and others (1984) found significant radial growth reduction of Pacific silver fir and western hemlock in an area with a 6- to 8-cm deposit of tephra. Douglas-fir at a site with 12 cm of tephra experienced a 9 to 31 percent reduction in the 1980 ring width compared to the 1979 ring width. Zobel and Antos (1985) found that tephra had little effect on annual Douglas-fir height growth at a site receiving 13 cm of tephra. In our study in northern Idaho, which received only about 1 cm of tephra, radial stem growth was not altered even though the ash persisted on the foliage. Neither the ratio of the 1980 to 1979 increment nor the ratio of the 1980 to 10-year mean increment (1970-79) was significantly different between stands (table 1).

In light of these data, we conclude that the 1980 ashfall from Mount St. Helens had little effect on Douglas-fir in northern Idaho, even though the tephra still persisted on the needles 16 months after the eruption. In spite of a small decrease in total chlorophyll and an increase in visible chlorosis, tree growth was unaffected as indexed by needles/shoot, needle dry weight, and radial stem growth. The eruption and associated ashfall were only a minor and temporary perturbation to Douglas-fir in northern Idaho.

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The May 18, 1980, eruption of Mount St. Helens deposited volcanic ash on forests of northern Idaho. Ash persisted on foliage of Douglas-fir (*Pseudotsuga menziesii* var. *glauca*)—12.8 to 15.7 mg ash/gram tissue dry weight remained on 1979 and 1980 needles 16 months following the eruption. Ashfall reduced chlorophyll concentrations and caused needle chlorosis but did not significantly influence tree growth.

KEYWORDS: Mount St. Helens, ash, *Pseudotsuga menziesii*, tephra, forest biology

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